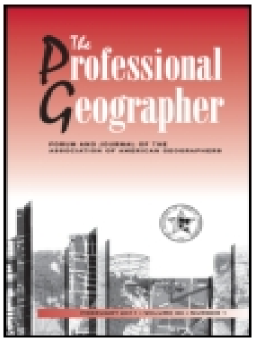

The Professional Geographer

ISSN: 0033-0124 (Print) 1467-9272 (Online) Journal homepage: https://www.tandfonline.com/loi/rtpg20

A Landscape in Transition: The Arbuckle Mountains, 1870 to 1898

Todd D. Fagin & Bruce W. Hoagland

To cite this article: Todd D. Fagin & Bruce W. Hoagland (2014) A Landscape in Transition: The Arbuckle Mountains, 1870 to 1898, The Professional Geographer, 66:3, 456-467, DOI: 10.1080/00330124.2013.848757

To link to this article: https://doi.org/10.1080/00330124.2013.848757

Published online: 26 Nov 2013.

A Landscape in Transition: The Arbuckle Mountains, 1870 to 1898*

Todd D. Fagin and Bruce W. Hoagland
University of Oklahoma

An understanding of the contemporary biogeography of a region must be predicated not only on the current environmental conditions that influence species distributions but also on historical factors including anthropogenic disturbance regimes. Increasingly, researchers are using historical data, such as the Public Land Survey System (PLSS) records, to create baselines from which subsequent biogeographic changes can be gauged. The present-day state of Oklahoma is unique in that two separate PLSS surveys were conducted in the state during a relatively short time span. We compare these two historical data sets, from the 1870s and 1890s, respectively, to quantify changes in landscape structure and woody plant assemblages corresponding to rapid demographic changes occurring within the Arbuckle Mountains in Oklahoma. During this period, the PLSS data show a landscape that became increasingly fragmented, as well as differences in stand composition and density. The documentation of these important historical anthropogenic changes occurring on the western fringes of the eastern deciduous forest could serve as a valuable guide for conservation and restoration initiatives. **Key Words: cross-timbers, eastern deciduous forest, historical vegetation reconstruction, Public Land Survey System.**

理解一个区域的当代生物地理, 不仅需以影响物种分佈的当前环境条件为依据, 亦需根据包含人类干扰的社会制度等历史因素。研究者正逐渐使用如公共土地调查系统 (PLSS) 纪录等历史数据, 创造后来的生物地理变迁进行测量所依据的基础。当今的奥克拉荷马州相当特别, 因为州内在相对而言很短的时间中, 分别进行了两项 PLSS 调查。我们分别比较 1870 年代与 1890 年代两个历史数据集, 用以量化奥克拉荷马的阿巴克尔山区中, 对应快速人口变迁而改变的地景结构与木本植物群落。在此期间, PLSS 数据显示出逐渐变得碎裂的地景, 以及林分组成与密度的差异。这些在东区落叶森林的西缘所发生的重要历史人类干扰改变的纪录, 可为保育和修復行动提供宝贵的指导方针。 **关键词: 十字木, 东落叶林, 历史植被再建构, 公共土地调查系统。**

La comprensión de la biogeografía contemporánea de una región debe formularse no solo en términos de las actuales condiciones ambientales que influencian la distribución de las especies sino también de factores históricos que incluyan los regímenes de perturbación antropogénica involucrados. Cada vez más los investigadores están haciendo uso de datos históricos, tales como los registros del Sistema Público de Estudios del Suelo (PLSDS), para crear bases de referencia a partir de las cuales puedan ser calibrados los cambios biogeográficos subsiguientes. El actual estado de Oklahoma es único en el sentido de que se dispone de dos estudios separados del PLSS efectuados allí dentro de un lapso relativamente corto. Comparamos estos dos conjuntos de datos históricos, de los años 1870 y los 1890, respectivamente, para cuantificar cambios en la estructura del paisaje y de las comunidades de plantas leñosas concurrentes con cambios demográficos rápidos ocurridos al interior de las Montañas Arbuckle de Oklahoma. Durante este período, los datos del PLSS muestran un paisaje que crecientemente se fue fragmentando, al tiempo que dejan ver las diferencias en composición y densidad de las unidades biogeográficas. La documentación de tan importantes cambios antropogénicos en los bordes occidentales de los bosques deciduos orientales podría servir como guía invaluable para acometer iniciativas de conservación y restauración. **Palabras clave: eco-región cross-timbers, bosque deciduo oriental, reconstrucción histórica de la vegetación, Sistema Público de Estudios del Suelo.**

Regional biogeographic patterns are not only the product of abiotic factors (e.g., climate, substrate, and topography) but of historical anthropogenic disturbance regimes, as well (Batek et al. 1999; Motzkin et al. 1999; Dupouey et al. 2002). In the time since European American settlement, the temperate forests and grasslands of North America have been modified by human activity (e.g., Curtis 1956; Forman 1995). In particular, land conversion for agriculture (e.g., ranching and row crop production), timber harvest, and expansion of human settlements have resulted in fragmented native ecosystems (Saunders, Hobbs, and Margules 1991; Forman 1995; Bennett and Saunders 2010). Additionally, fire suppression has led to increased abundance of woody vegetation at the expense of grasslands (Archer 1995; Engle, Bidwell, and Moseley 1997) and canopy closure in woodlands, which displaces understory species (Engle, Bodine, and Stritzke 2006; Nowacki and Abrams 2008). Concurrently, fire suppression can result in more mesophytic conditions in erstwhile pyrogenic habitats (Nowacki and Abrams 2008). In both instances, the result is often a difference in species assemblages than in predisturbed habitats.

Many studies have quantified the spatial extent and rates of land conversion using historical data sources such as land survey data, aerial photography, and satellite imagery. These data are typically compiled

*The authors would like to thank Drs. Tom Wikle, J. Scott Greene, Aondover Tarhule, Robert Rundstrom, and Wayne Elisens, as well as the anonymous reviewers, for their valuable feedback during the preparation of this article.

The Professional Geographer, 66(3) 2014, pages 456–467 © Copyright 2014 by Association of American Geographers.
Initial submission, October 2012; revised submission, February 2013; final acceptance, February 2013.
Published by Taylor & Francis Group, LLC.

into an analysis of temporal sequences, starting with a baseline from which subsequent change can be gauged. As such, they provide valuable insight into land cover changes and its effects on ecosystem structure and function (e.g., Maines and Mladenoff 2000; Bahre and Hutchinson 2001; Fritschle 2008). These analyses, in turn, can guide conservation and habitat restoration efforts based on the established baseline (Radeloff, Mladenoff, and Boyce 2000; Bolliger et al. 2004).

As useful as these data might be, there is often a significant temporal gap between the various data sources. For instance, in much of the United States, a century or more elapsed between the nineteenth-century land surveys and the advent of aerial photography. Significant changes in land cover likely occurred in that interval, but evidence supporting this assertion is often elusive. Further compounding the problem, much of the available baseline data, such as the Public Land Survey System (PLSS) records of the General Land Office (GLO), were collected only after widespread anthropogenic modifications to landscapes occurred. Moreover, these data were often collected once and over protracted periods of time (Schulte and Mladenoff 2001). One notable exception is the Public Land Survey of Oklahoma, which was conducted over a relatively short period of time and completed twice.

The GLO surveyed the present-day state of Oklahoma, then known as Indian Territory, first in the early 1870s and again in the late 1890s (Hoagland 2006), thus providing two late nineteenth-century data sets collected using the same protocols and mandates. The PLSS records are one of the few quantitative data sets of pre- and early-European American settlement that provide both land cover and taxonomic data for analysis of vegetation composition. Despite the inherent limitations (Bourdo 1956; Schulte and Mladenoff 2001; Whitney and DeCant 2001), the notes, witness tree records, and plat maps of the PLSS have contributed to our understanding of past ecological conditions and in the evaluation of human modification of the landscape (e.g., Curtis 1956; Mladenoff and Howell 1980; Smith, Marks, and Gardescu 1993; Zhang, Pregitzer, and Reed 2000).

The interval between the two surveys in Indian Territory was a period of rapid demographic change, including railroad development, rapidly expanding towns, and new agricultural-based economies (Gibson 1981). However, a spatial analysis and evaluation of ecological and biogeographical consequences of these demographic shifts are lacking. As such, these PLSS records could provide valuable insight into the degree of ecological transformation, if any, that corresponds to this period of demographic shift.

The goal of this study is to evaluate the historic land cover change in the Arbuckle Mountains of south-central Oklahoma. Utilizing repeat PLSS data, we analyzed landscape structure and associated woody plant assemblages at two discrete points in time, one corresponding to the period immediately prior to extensive European American settlement (1870s), the other following settlement (1890s). Our analyses include the quantification of landscape and habitat fragmentation by comparing land cover maps derived from the plats of the two survey periods and an analysis of changes in the distribution and composition of woody plant taxa between the two survey periods. The results of this study will provide important insight on relatively short-term biologic effects of habitat fragmentation and provide useful baselines from which to gauge additional landscape change.

Methods

Study Area

The Arbuckle Mountains cover an area of approximately 215,000 ha in south-central Oklahoma (Figure 1). The Arbuckle Mountains, topographically a low plateau, rise a few hundred feet meters above the surrounding prairie, sloping from an elevation of 411 m (1,350 ft) in the west to 229 m (750 ft) in the east (Dale 1956; Hutcheson 1965) and consist of areas of considerable faulting and folding, resulting in many unusual structural features. The geologic history of the region has led to the exposure of thick late Cambrian to middle Mississippian limestone sediment and late Mississippian and Pennsylvanian sedimentary rocks (Suneson 1997). Outcrops of mostly carbonate rocks characterize the surface geology, although granitic outcrops surrounded by limestones, conglomerates, sandstones, shales, cherts, and other types of rocks are prevalent (Dale 1956; Suneson 1997).

The study area is located in the Subtropical Humid (Cf) climate zone, which is characterized by long, hot summers and short, mild winters (Trewartha 1980). Summer temperatures average 28°C, and winter temperatures average 4°C. Mean annual precipitation is approximately 1,010 mm, with much of it occurring in April, May, and June (National Climatic Data Center 2012). November, December, January, and February are the driest months, although drought conditions as reflected by the vegetation typically occur in July and August (Dale 1956).

The Arbuckle Mountains lie within the cross-timbers, a region characterized by a mosaic of forest, woodland, and prairie vegetation. The forest and woodland vegetation of the cross-timbers is dominated by two species of woody plants, *Quercus stellata* and *Q. marilandica*, whereas the grassland communities are dominated by *Andropogon gerardii*, *Panicum virgatum*, *Schizachyrium scoparium*, and *Sorhastrum nutans* (Hoagland et al. 1999). Reduction of native fire regimes during the past century, however, has resulted in the increase of woody plants (particularly *Juniperus* spp.) at the expense of grassland (Archer 1995; Engle, Bidwell, and Moseley 1997) and is believed to have led to the increased canopy cover of dominant overstory *Quercus* spp. (Engle, Bodine, and Stritzke 2006).

Vegetation studies of the Arbuckle mountains (e.g., Hopkins 1941; Dale 1956; Rice and Penfound 1959; Hutcheson 1965; Johnson and Risser 1975) have shown that woodland communities vary considerably with soil type and moisture availability, with *Q. stellata* and *Q. marilandica* as codominants in dry

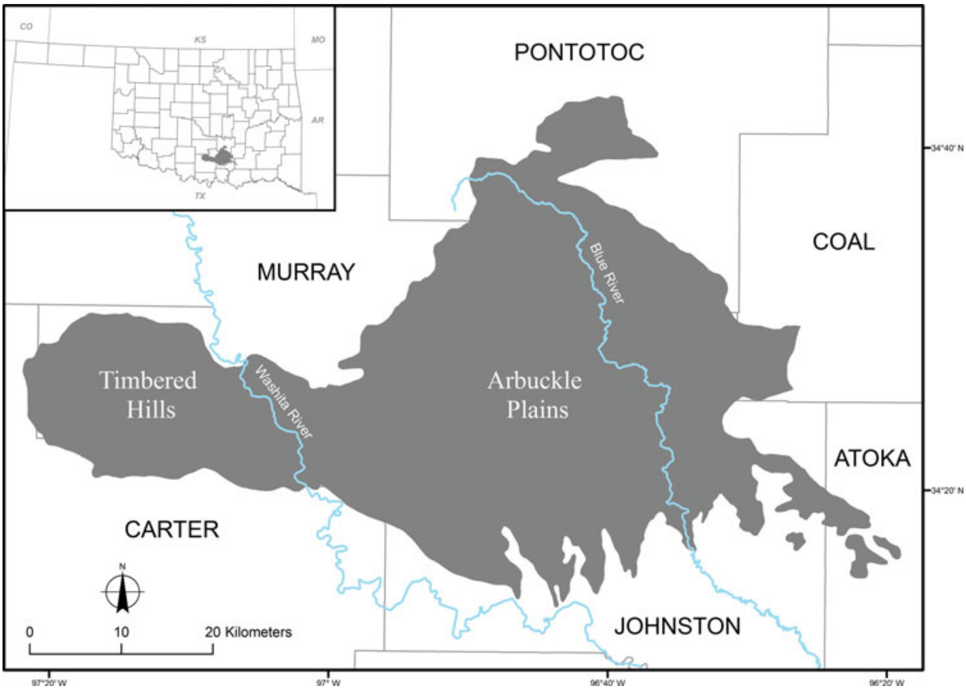

Figure 1 *Study area location in south-central Oklahoma. (Color figure available online.)*

upland areas of granitic and calcareous parent material. *Carya texana* is another important upland species in the cross-timbers, typically found in drier portions of the *Quercus-Carya* forest types. Important bottomland species include *Q. muhlenbergii*, *Celtis laevigata*, *C. laevigata* var. *reticulata*, *Platanus occidentalis*, *Ulmus americana*, *U. rubra*, *Carya illinoensi*, *Juglans nigra*, *Salix nigra*, and *Populus deltoides* (Dale 1956; Rice and Penfound 1959; Kennedy 1973).

The cross-timbers reside on the western edge of the eastern deciduous forest and the eastern edge of the Great Plains. Consequently, the Arbuckle Mountains are home to a diversity of flora and fauna, including a number of species of concern from a conservation perspective, including *Alnus maritima*, *Epipactis gigantea*, *Penstemon oklahomensis*, *Psoralea reverchonii*, and *Aquila chrysaetos*.

From a historical perspective, the Arbuckle Mountains are believed to have undergone rapid ecological changes in the period since widespread European American settlement. In particular, fire suppression and other land use practices have led to increases in *Juniperus virginiana* and *J. asheii* at the expense of grasslands and are believed to have contributed to the densification of wooded areas (Hoagland et al. 1999). Additionally, habitat fragmentation has led to a decrease of native habitats and an increase of anthropogenic land cover types. Despite these ecological transformations, there is a dearth of quantitative research on these biotic conditions prior to these anthropogenic changes. The Arbuckle Mountains' position within the boundaries of the Chickasaw Nation provide two quantitative historical data sets, one preceding widespread European American settlement, the other immediately following a substantial demographic shift, thereby enabling an analysis of these dynamics and the ecological consequences thereof.

Data Analysis

The PLSS records were standardized in 1855 (Moore 1855) and contain two types of data that are useful for the analysis of historic vegetation. As surveyors partitioned the land into a grid of 93.24 km^2 (36 mi^2) townships and further subdivided each township into 2.59 km^2 (1 mi^2) sections, surveyors documented prominent features, such as the location of barrens, prairies, scrublands, and forests; natural disturbances, such as windfalls and erosion; and, in some instances, evidence of recent fires (Whitney and DeCant 2001; Wang 2005). On returning from the field, these data were compiled into a series of township-wide plats from the areas surveyed.

Surveyors also recorded quantitative information related to "witness" trees encountered along the survey lines. These data were recorded at the intersection of section lines, where surveyors noted the nearest tree in each of the adjoining sections, recording its identification and estimated diameter at breast height (DBH) and compass direction and distance from the corner section. Surveyors recorded the same information at each quarter section point but only for the trees nearest the adjoining sections (Moore 1855; L. O. Stewart 1935; Hutchison 1988). As a result, each corner section could have up to four witness trees and each quarter section a maximum of two trees (Figure 2).

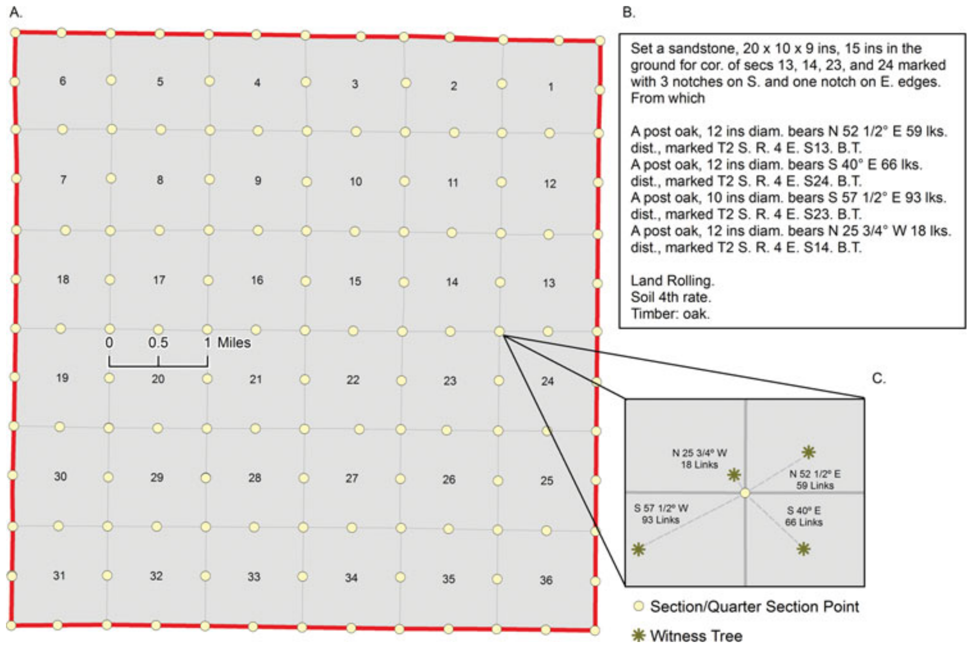

Figure 2 *(A) Schematic of section line intersection and quarter section points from which surveyors recorded the identification, estimated diameter at breast height, compass direction, and distance to the nearest tree in each adjoining section. Each corner section could have up to four so-called witness trees, and each quarter section a maximum of two trees. (B) Transcribed excerpt from surveyor notes indicating witness tree information recorded from a section corner. Quarter section points would only have up to two trees, one in each adjoining section. (C) An example of plotted witness tree data from surveyor notes. (Color figure available online.)*

We obtained microfiche copies of transcribed surveyor notes and digital (scanned) township plats for the study area. The forty townships encompassing the study area were first surveyed between the years of 1870 and 1872, with the majority of the surveys (thirty-five) occurring in 1871. The entire 1870s survey of the study area spanned 1.25 years (November 1870–February 1872). Each of the forty townships was resurveyed from November 1897 through December 1898, with most of the surveys (thirty) conducted throughout 1898. Overall, there was an average of 26.6 years (26 years, 7 months) between the original survey and resurvey (Table 1).

We georeferenced each scanned image using a digital township, range, and section data set for the study area obtained from the Bureau of Land Management's Land Survey Information System. We digitized relevant features from each PLSS plat, including land cover types, transportation networks, and anthropogenic structures, into a series of seamless geographic information system (GIS) layers (land cover, transportation, and structures). The resulting land cover layers consisted of features delineated by surveyors as forest/woodland, grassland (i.e., nonwooded, vegetated areas, which can include pasture land), cultivated areas, and wetlands. The transportation network layers included features identified as wagon roads, cattle trails, other trails, and railroads. The anthropogenic structure layers consisted of any point features that surveyors marked as anthropogenic in origin, such as various buildings, mines, and gins.

To quantify change in land cover between the two survey dates, we calculated several landscape indexes for each survey period: class area (measure of total area occupied by a particular land cover type), number of patches (measure of individual occurrences of a given land cover type), and mean patch size (average area occupied by each land cover type; Rempel 2008). We identified and quantified areas of change by combining each time-stamped GIS layer into a single composite layer using a GIS overlay operation (Langram and Chrisman 1988). We also generated summary statistics, which served as surrogate measures of anthropogenic influences on the landscape, of all other data layers (e.g., transportation networks and anthropogenic structures).

Witness tree records for corner and quarter sections were databased. Data relevant to this study recorded by surveyors included common name of the tree encountered, to which we attempted to apply an appropriate scientific binomial, estimated DBH, and compass bearing and distance from the corner or quarter section point.

We calculated mean distance from each survey point to recorded trees (Batek et al. 1999), as well as tree density using the point-centered quarter method (Cottam and Curtis 1956; Anderson, Jones, and Swigart 2006). To determine the structure of woody vegetation, we calculated basal area (πr^2) using DBH,

Table 1 *Month and year of the Public Land Surveys of the Arbuckle Mountains, 1870s and 1890s*

1870s				1890s			
Month	Year	Deputy surveyor	Township	Month	Year	Deputy surveyor	Span (Years)
Sep.	1871	Ehud Noble Darling	1N4E	Nov.	1897	Frank E. Lewis	26.17
Aug.	1871	Ehud Noble Darling	1N5E	Feb.	1898	Fred Watts Jr.	26.50
Oct.	1871	Ehud Noble Darling	1N6E	Feb.	1898	J. P. Thayer	26.33
Oct.	1871	Ehud Noble Darling	1N7E	Dec.	1898	Fred Watts Jr	27.17
Dec.	1870	Ehud Noble Darling	1S1E	Dec.	1897	J. C. Wilkinson	27.00
Dec.	1870	Theodore H. Barrett	1S1W	Jun.	1898	Wm O. Beall	27.50
Feb.	1871	Ehud Noble Darling	1S2E	Dec.	1897	Oscar Jones	26.83
Feb.	1872	Theodore H. Barrett	1S2W	May	1898	Frank F. Sweet	26.25
Sep.	1871	Ehud Noble Darling	1S3E	Feb.	1898	J. C. Wilkinson	26.42
Jun.	1871	Ehud Noble Darling	1S4E	Feb.	1898	Oscar Jones	26.67
Jun.	1871	Ehud Noble Darling	1S5E	Jan.	1898	Thr Johnson	26.58
Sep.	1871	Ehud Noble Darling	1S6E	Jan.	1898	J. W. Riley	26.33
Sep.	1871	Ehud Noble Darling	1S7E	Feb.	1898	J. W. Riley	26.42
Sep.	1871	Ehud Noble Darling	1S8E	Feb.	1898	J. W. Riley	26.42
Oct.	1871	Ehud Noble Darling	2N4E	Dec.	1897	Frank E. Lewis	26.17
Aug.	1871	Ehud Noble Darling	2N5E	Feb.	1898	Fred Watts Jr.	26.50
Oct.	1871	Ehud Noble Darling	2N6E	Feb.	1898	J. P. Thayer	26.33
Oct.	1871	Ehud Noble Darling	2N7E	Dec.	1897	Fred Watts Jr.	26.17
Nov.	1870	Ehud Noble Darling	2S1E	Dec.	1897	Frank E. Lewis	27.08
Nov.	1870	Theodore H. Barrett	2S1W	Jun.	1898	Geo W. Hooper	27.58
Jan.	1871	Ehud Noble Darling	2S2E	Dec.	1897	Frank E. Lewis	26.92
Jan.	1871	Theodore H. Barrett	2S2W	Jun.	1898	J. E. Beavers	27.42
Sep.	1871	Ehud Noble Darling	2S3E	Jan.	1898	George A. Purington	26.33
Jun.	1871	Ehud Noble Darling	2S4E	Jan.	1898	Frank E. Lewis	26.58
Jul.	1871	Ehud Noble Darling	2S5E	Jan.	1898	Fred Watts Jr.	26.50
Sep.	1871	Ehud Noble Darling	2S6E	Jan.	1898	J. P. Thayer	26.33
Sep.	1871	Ehud Noble Darling	2S7E	Feb.	1898	Thr Johnson	26.42
Sep.	1871	Ehud Noble Darling	2S8E	Feb.	1898	J. W. Riley	26.42
Sep.	1871	Ehud Noble Darling	3N5E	Jan.	1898	Fred Watts Jr.	26.33
Oct.	1871	Ehud Noble Darling	3N6E	Feb.	1898	J. P. Thayer	26.33
Jan.	1871	Ehud Noble Darling	3S2E	Dec.	1897	Oscar Jones	26.92
Jul.	1871	Ehud Noble Darling	3S3E	Jan.	1898	J. C. Wilkinson	26.50
May	1871	Ehud Noble Darling	3S4E	Jan.	1898	Oscar Jones	26.67
Jul.	1871	Ehud Noble Darling	3S5E	Jan.	1898	Thr Johnson	26.50
Aug.	1871	Ehud Noble Darling	3S6E	Jan.	1898	J. W. Riley	26.42
Aug.	1871	Ehud Noble Darling	3S7E	Feb.	1898	Thr Johnson	26.50
Aug.	1871	Ehud Noble Darling	3S8E	Feb.	1898	J. W. Riley	26.50
May	1871	Ehud Noble Darling	4S4E	Jan.	1898	Oscar Jones	26.67
Apr.	1871	Ehud Noble Darling	4S5E	Dec.	1897	Thr Johnson	26.67
Jun.	1871	Ehud Noble Darling	4S6E	Dec.	1897	J. W. Riley	26.50

relative dominance (basal area individual taxon/basal area all taxa), relative density (number of individuals of a taxon/number of all individuals in all taxa), and importance value (IV; average of relative density and relative dominance) for each taxon for each surveyed period. To determine whether there were compositional and structural differences in woody plant taxa between the two survey periods, we calculated the Sørensen index (Sørensen 1957) and Bray–Curtis dissimilarity index (Bray and Curtis 1957), respectively, and used a *t* test to determine whether there were significant differences between DBH (entire data set, as well as individually for top five taxa), average point to tree differences, and density values between the two surveys. All of the preceding measurements excluded areas in which no witness trees were recorded.

Results

Landscape Change and Fragmentation

During the 1870s, PLSS plats depicted the landscape of the Arbuckle Mountains as primarily a mosaic of forest/woodland and grassland vegetation with little evidence of human habitation or direct anthropogenic landscape modifications (Figure 3). Grasslands were the dominant land cover type, followed by forest/woodland. Cultivated lands, consisting of gardens, orchards, and farmed lands, covered only a fraction of total land area. Additionally, as Table 2 indicates, there were few anthropogenic structures within the area and those present were primarily residential. The low anthropogenic signal is further reflected in the scarcity of recorded transportation networks (Table 3, Figure 3).

By the 1890s, the landscape had undergone rapid change, characterized by increased habitat fragmentation as a result of forest/woodland clearance, a dramatic increase in cultivated areas, and the built environment. During this period, the forest/woodland cover class decreased by approximately 23 percent, whereas areas mapped as grasslands (including possible pasture lands) increased slightly (see Figure 3). Cultivated areas showed the greatest change between the two survey years. Additionally, anthropogenic structures increased more than twenty-five-fold in the area and the total linear distance of transportation

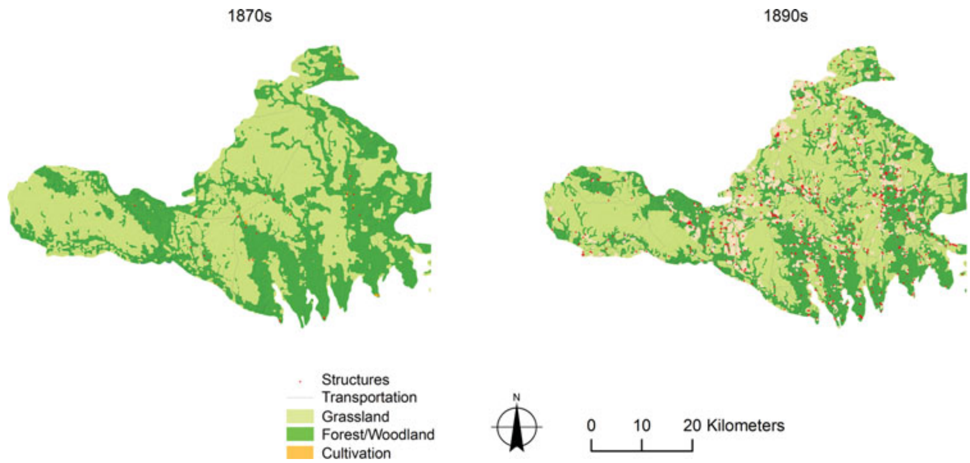

Figure 3 *Land cover of the Arbuckle Mountains in the 1870s and 1890s, respectively, including anthropogenic structures and transportation networks, as depicted on the Public Land Survey plats. (Color figure available online.)*

networks increased by more than fivefold (see Tables 2 and 3, Figure 3).

These changes are further reflected in the overall patchiness of the landscape and the directions of change (Figure 4). Both forest/woodland and grassland patches increased in number, although the mean patch size of each decreased, indicating a trend toward greater fragmentation. The greatest landscape change occurred in the form of forest/woodland conversion to grasslands (including pasturelands). There is also evidence, however, of afforestation in areas formerly mapped as grasslands. Moreover, both forest/woodland and grasslands areas were cleared for cultivation during the period under consideration, and there is limited evidence of agriculture abandonment.

Composition and Vegetation Structure

There were 2,502 possible corner or quarter section points in the study area from which woody plant taxa could be recorded. Overall, there was a combined total of thirty different taxa recorded from 1,416 (57 percent) survey points during the two surveys. In the 1870s, surveyors recorded 2,578 individual trees representing twenty-eight different taxa from 1,088 (43 percent) survey points (Table 4). *Quercus stellata* had the highest frequency of recorded trees. Other commonly reported taxa included *Q. velutina*, *Ulmus* spp., and *Carya texana*. In the 1890s, a total of 2,980 individual trees representing twenty-five different taxa were recorded from 1,261 (50%) survey points (Table 4). *Quercus stellata* was once again the most abundant species. *Ulmus* spp., *Q. marlandica*, *Q. falcata*, and *Carya illinoinensis* were also commonly reported. Both compositionally and structurally, the landscape was similar between the surveys (83.6 percent similarity and 72.9 percent similarity, respectively).

In the 1870s, trees averaged 16.07 m in distance from the survey points and the average density in areas in which trees were recorded was 148.55 stems/ha. By contrast, in the 1890s, trees averaged 21.16 m in distance and the average density in areas in which trees were recorded was 78.99 stems/ha.

T-test results indicate that although there was not a significant difference in DBH for all taxa and density between the two survey periods, $t(0.182)$, $p = 0.856$; $t(-1.24)$, $p = 0.168$, respectively, there was a significant difference between average distance from survey points to witness trees between the two years, $t(-9.15)$, $p < 0.00$. T-test results indicate that DBH of each of the five dominant taxa did not vary significantly between the two surveys. Due to possible

Table 2 *Comparison of 1870s and 1890s structures from Public Land Survey plats*

Structure type	1870s	1890s
Residential	24	787
Store	2	2
Post office	1	7
Mill	1	1
Capital	1	0
Blacksmith	1	1
School house	0	11
Church	0	2
Cemetery	0	2
Mine	0	1
Tank	0	2
Triangulation signal	0	1
Gin	0	3
Sawmill	0	1
Total	30	821

Table 3 *Comparison of the linear difference in kilometers of the 1870s and 1890s transportation networks from Public Land Survey plats*

Transportation	1871	1897
Wagon road	202.64	1,703.23
Trail	28.55	0
Cattle trail	31.80	0
Railroad	0	63.66
Total length (km)	262.99	1,766.89

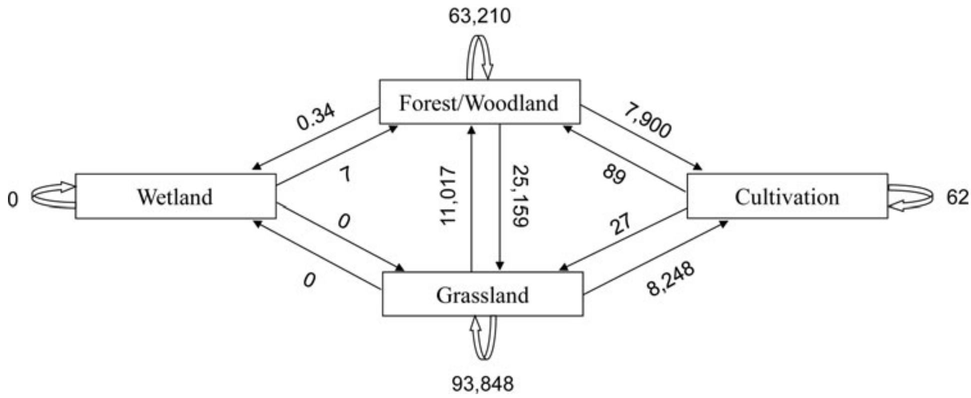

Figure 4 *Trajectories of change: Arrows indicate the direction of change from one land cover class to another between the two survey periods. All values listed are hectares. For instance, between the 1870s and 1890s surveys, 25,159 ha of forest/woodland was converted to grassland (or nonforested pasture) and 8,248 ha of grassland was converted to cultivation.*

nomenclature issues pertaining to survey use of "black oak" and "blackjack oak," however, we also tested differences between 1870s DBH values for "black oak" and 1890s values for "blackjack oak." There was a significant difference between these means, $t(3.289)$, $p = 0.001$. Nonetheless, we found that the taxonomic composition between the two surveys was mostly similar (0.836 and 0.728 similarity based on the Sørensen and Bray–Curtis indexes, respectively).

Discussion

Land Use Change and Fragmentation

Permanent settlements in the Arbuckle Mountains began in the late 1850s with the establishment of Fort Arbuckle in current-day Murray County and the movement of translocated Chickasaw into their federally established district (Gibson 1981). The gradual movement of both Chickasaws and European

Table 4 *Comparison of frequency, relative dominance, relative density, and importance value for all recorded taxons, 1870s and 1890s*

	1870s				1890s			
Taxon	No. trees	Relative dominance	Relative density	Importance value	No. trees	Relative dominance	Relative density	Importance value
Quercus stellata	1,234	46.368	47.867	47.117	1,242	40.331	41.678	41.005
Quercus velutina	529	15.442	20.520	17.981	73	2.509	2.450	2.479
Ulmus spp.	328	29.296	12.723	21.009	474	21.174	15.906	18.540
Carya texana	118	0.982	4.577	2.779	69	0.568	2.315	1.441
Quercus alba	81	1.701	3.142	2.422	57	0.739	1.913	1.326
Carya illinoinensis	56	1.231	2.172	1.702	123	5.459	4.128	4.793
Fraxinus spp.	45	0.983	1.746	1.364	69	1.324	2.315	1.820
Quercus falcata	37	0.607	1.435	1.021	184	5.713	6.174	5.944
Celtis laevigata	24	0.416	0.931	0.673	58	1.261	1.946	1.603
Juglans nigra	23	0.493	0.892	0.693	42	2.236	1.409	1.822
Quercus palustris	22	0.209	0.853	0.531	27	0.448	0.906	0.677
Populus deltoides	19	0.744	0.737	0.740	6	0.200	0.201	0.201
Quercus macrocarpa	18	0.658	0.698	0.678	19	0.567	0.638	0.602
Quercus marilandica	6	0.386	0.233	0.309	315	12.541	10.570	11.556
Platanus occidentalis	6	0.042	0.233	0.138	6	0.287	0.201	0.244
Diospyros virginiana	5	0.262	0.194	0.228	17	0.388	0.570	0.479
Juniperus spp.	4	0.055	0.155	0.105	7	0.204	0.235	0.219
Cercis canadensis	4	0.003	0.155	0.079	—	—	—	—
Morus rubra	3	0.028	0.116	0.072	—	—	—	—
Quercus spp.	3	0.014	0.116	0.065	164	3.600	5.503	4.552
Maclura pomifera	3	0.018	0.116	0.067	11	0.351	0.369	0.360
Sideroxylon lanuginosum	2	0.022	0.078	0.050	7	0.024	0.235	0.129
Prunus spp.	2	0.004	0.078	0.041	—	—	—	—
Acer negundo	2	0.024	0.078	0.051	2	0.023	0.067	0.045
Malus ioensis	1	0.001	0.039	0.020	—	—	—	—
Gymnocladus dioicus	1	0.004	0.039	0.022	1	0.004	0.034	0.019
Salix spp.	1	0.001	0.039	0.020	1	0.001	0.034	0.017
Crataegus spp.	1	0.010	0.039	0.024	—	—	—	—
Quercus nigra	—	—	—	—	5	0.046	0.168	0.107
Sapindus saponaria	—	—	—	—	1	0.002	0.034	0.018

Americans into the Arbuckle Mountains regions is reflected in the 1870s surveys. Few anthropogenic structures existed throughout the 215,000-ha area and agriculture was limited primarily along rivers and streams in small plots likely used for subsistence purposes (Gibson 1981).

Nonetheless, land modifications likely existed during this period, although not recorded in the survey notes or plats. For instance, the Chickasaw maintained large herds of domesticated animals prior to removal (Morris 1947; Doran 1976). On arrival to their new lands, the Chickasaw continued ranching and even expanded their enterprise due to opportunities presented by the extensive prairies in their new home (Gibson 1981). An enumeration in the Chickasaw Nation in the 1850s counted 14,788 domestic animals (Doran 1976).

Additionally, other anthropogenic modifications to the environment, such as intentionally set fires in prairies, have been documented in the area (O. C. Stewart 2002). Early traveler accounts of the area (Dyksterhuis 1948) reference frequent fires throughout the cross-timbers. As Irving ([1835] 1959, 125) wrote of the cross-timbers, "[t]he fires made on the prairies by the Indian hunters, had frequently penetrated these forests, sweeping in light transient flames along the dry grass, scorching and calcining the lower twigs and branches of the trees, and leaving them black and hard."

The 1870s surveyor notes are limited in their description of such land use practices within the Arbuckle Mountains. Although the surveyors documented general landscape characteristics (Fagin and Hoagland 2002), there is little mention of specific enterprises such as ranching (although surveyors did map approximately 32 km of cattle trails in the area during the 1870s survey). Additionally, the notes for the Arbuckle Mountains do not contain any mention of recent fire. Nonetheless, the ecological implications of increased ranching, fire abatement, or both are many. Both ranching and fire suppression have been shown to be critical factors in the increase of some woody species (Briggs, Hoch, and Johnson 2002), and fire suppression is believed to be a driving factor in the increased densification of wooded and forested areas (Dyksterhuis 1948, 1957; Rice and Penfound 1959; Engle, Bodine, and Stritzke 2006; Nowacki and Abrams 2008).

In the period following the U.S. Civil War, the Chickasaw Nation saw rapid growth as new rail lines transecting the Chickasaw Nation were built. By the 1890s, eight new towns, each with populations in excess of 1,000, sprouted up along the railroad lines in the Chickasaw Nation. By 1900, an estimated 150,000 whites, some legally, others illegally, were living in the Chickasaw Nation (Gibson 1981).

Accompanying this rapid demographic shift was an intensification of land use practices, primarily in the expansion of large-scale agriculture. In 1886, the superintendent of the Five Civilized Tribes reported that agriculture in the Chickasaw Nation was increasing geometrically, having already doubled in the last five years (Owen 1886). Additionally, ranching intensity continued to increase and new pressures on the land, primarily in the realm of natural resource extraction (oil and coal), were introduced (Gibson 1981).

The intensified land use practices between the two surveys are reflected in the increased patchiness of the landscape (Figure 3). This habitat fragmentation is of particular ecological concern. As an ecosystem is reduced in areal extent, changes in the biogeography of the remnant ecosystem often result. In particular, a series of vegetation patches is produced (Forman 1995). These vegetation patches are further influenced by alterations in the physical environment, which are themselves a product of fragmentation. The result is often markedly different species composition within patches than that of the prefragmented ecosystem.

Species Composition and Structure

The woody species assemblages from the two survey periods tend to correspond to twentieth-century vegetation studies in the region (e.g., Dale 1956; Rice and Penfound 1959). Some peculiarities exist, however. For instance, studies have determined that *Q. stellata* and *Q. marilandica* are the most important woody species in the region, accounting for 90 percent of the canopy cover and 50 percent of basal area of the cross-timbers (e.g., Rice and Penfound 1959; Johnson and Risser 1975; Hoagland and Johnson 2001). During the 1870s' survey, though, the second most commonly reported *Quercus* species (behind *Q. stellata*) was *Q. velutina* (529 occurrences), which the surveyors identified as "black oak." *Quercus marilandica*, identified as "blackjack" by the surveyors, was only recorded six times (compared to 315 in the 1890s; Table 4).

Although *Q. velutina* has been documented in the region (Dale 1956; Rice and Penfound 1959; Hutcheson 1965), it reaches its western extent in central Oklahoma (Little 2000) and, with the exception of Hutcheson (1965), has not been frequently reported in the Arbuckle Mountains. Hoagland and Johnson (2001) did not record any instances of *Q. velutina* within the Chickasaw National Recreation Area (located in the Arbuckle Plains physiographic province), and the Oklahoma Vascular Plants Database (Hoagland et al. 2008) only contains twenty-one records for *Q. velutina* within the six counties of the Arbuckle Mountains.

There are several possibilities for the seemingly anomalous *Q. velutina* records. In the field notes, surveyors recorded trees by common name (Fagin and Hoagland 2002) and surveyors rarely had formal botanical training (Delcourt and Delcourt 1996). Misidentification and use of regional or outdated common names presents a unique challenge in attributing the correct scientific binomial in vegetation reconstructions from PLSS data. Surveyors, for instance, might have applied the common name "black oak" to *Q. marilandica* rather than *Q. velutina*. Moreover, surveyors might have confounded *Q. velutina* with several other *Quercus* species conspicuously absent from the field notes, such as *Q. buckleyi* or *Q. shumardii.*

Another possibility is that the *Q. velutina* identification is correct. Hutcheson's (1965) study of the vegetation of the Timbered Hills of the Arbuckle Mountains, for instance, found that *Q. velutina* was the most abundant woody species on north-facing slopes of limestone origin and of secondary importance on south-facing slopes. Additionally, the results of our statistical analysis comparing the DBH of 1870s *Q. velutina* to 1890s *Q. marilandica* under the assumption that survey use of "black oak" indicated *Q. marilandica* found that there was a significant difference in the means of the two sets.

Aside from these differences, the composition of the woodland and forests of the Arbuckle Mountains in the 1870s and 1890s, respectively, are roughly analogous to more contemporary studies of the region (Hoagland and Hough 2008). Due to taxonomic uncertainties, we are unable to definitively ascertain whether rapid land conversion in the area between the two survey periods resulted in compositional differences in the arborescent communities of the Arbuckle Mountains. The differences in recorded *Q. velutina* and *Q. marilandica* is the most striking difference between the two surveys, especially when compared to the contemporary composition of the upland forests of the Arbuckle Mountains. Additionally, the infrequency of *Juniperus* spp. records seem to confirm prior assessments (e.g., Johnson and Risser 1975; Engle, Bidwell, and Moseley 1997) of limited distribution prior to widespread fire suppression and other land use practices.

The apparently restricted distribution of *Juniperus* spp. is of particular note vis-à-vis habitat restoration. Within the Arbuckle Mountains, there are two species primarily responsible for woody plant encroachment, *Juniperus virginiana* and *J. ashei.* During the past fifty years, both species have increased their ranges, primarily due to fire suppression and other land use practices (Engle, Bidwell, and Moseley 1997). Although numerous attempts have been made to quantify the degree and direction of the increases in abundance of these species (e.g., Briggs, Hoch, and Johnson 2002), few studies have established baselines from periods preceding widespread fire abatement.

Although there are limited compositional differences between the two survey periods, the historical structure of these forests is of particular note. It has long been posited that the arborescent communities of the cross-timbers, like much of the eastern deciduous forest, were less dense in historical times (e.g., Dyksterhuis 1957; Rice and Penfound 1959; Engle, Bodine, and Stritzke 2006). Accordingly, prior to widespread European American settlement, much of the contemporary forests of the cross-timbers was woodland and "savanna." Fire suppression and other land use practices have contributed to an increase in density of dominant overstory *Quercus* species (Engle, Bodine, and Stritzke 2006).

Rice and Penfound's (1959) study of the upland forests of Oklahoma represents one of the few quantitative studies of the postsettlement structure of the forests in the Arbuckle Mountains region. Their summary data (Hoagland and Hough 2008) indicate that, at the time of their analyses, the average density of the upland forests in the counties encompassing the Arbuckle Mountains was 216.68 trees/ha. We found that historically density values varied throughout the arborescent communities in the Arbuckle Mountains. During the 1870s, the average density of all points from which trees were recorded was 148.55 trees/ha. By the 1890s, the average density had decreased to 78.99 trees/ha, which likely corresponds to the decrease in forest/woodland cover during the period between the two surveys.

PLSS data confirm historically less dense cross-timbers within the Arbuckle Mountains, but surveyor bias in witness tree selection can affect these estimates. Although surveyors were instructed to record the bearing, distance, and diameter to the nearest tree in each adjacent section, witness tree selection was often influenced by tree size, conspicuousness in a stand, longevity, or economic value (Lutz 1930; Bourdo 1956; Kronenfeld and Wang 2007). Additionally, differences in survey instructions and ecological and environment heterogeneity have been demonstrated to influence witness tree selection (Liu et al. 2011). Although this might influence the analysis of stem density on a species-by-species basis, the PLSS data should provide a relatively effective estimate of density when all stems are considered together.

Survey methods were standardized by the time of both of Oklahoma's surveys (Moore 1855) and, therefore, both should have been conducted using similar protocols. Nonetheless, some differences in the survey methods could be attributed to the individuals who conducted the surveys. One indication of these differences is the number of deputy surveyors contracted. In the 1870s, only two deputy surveyors were contracted to survey the townships under consideration, one of whom oversaw the survey of 90 percent of the townships. By contrast, thirteen different deputy surveyors were contracted to conduct the resurvey, and no single individual oversaw more than seven townships (Table 1).

The point-centered quarter method assumes unbiased tree selection (Cottam and Curtis 1956). As a result, PLSS data might actually underestimate historical tree densities because selected witness trees were not necessarily the closest individual to each survey point. Assuming similar biases from each survey period, the data provide density indexes useful for comparing the two surveys (Grimm 1984). The decrease in density between the 1870s and 1890s is not surprising given the documented land clearance (Shutler and Hoagland 2004) that occurred during this period. This raises interesting questions about the basis of long-held assumptions of less dense savannas and woodlands in the cross-timbers prior to European American settlement. Although experiments (e.g., Johnson and Risser 1975; Engle, Bodine, and Stritzke 2006) indicate that fire is an important maintenance factor in cross-timber, most accounts of the savanna-like nature of the cross-timbers in the region are based on early settler accounts (Dyksterhuis 1948; Rice and Penfond 1959). These claims, then, might be based on evidence after substantial change in the landscape occurred.

Conclusion

The decades immediately following the Chickasaw's arrival in the Arbuckle Mountains region are characterized by a landscape in transition. Widespread habitat fragmentation for agriculture and other commercial enterprises resulted in the reduction of both the areal extent and overall density of forest and woodland vegetation. Despite lack of strong evidence that these changes had an immediate impact on the overall composition of the woody taxa in the region, they nonetheless provide important insights into the pre-European American ecology of the cross-timbers of the Arbuckle Mountains. The repeat PLSS data for the Arbuckle Mountains indicate a possible shift in importance of *Q. velutina* and *Q. marilandica* in the period proceeding European American settlement; confirm less dense arborescent communities in historic times; and show an extremely low abundance of *Juniperus* spp. compared to the present.

Because the cross-timbers are a mosaic of forest, woodland, and prairie vegetation, another caveat to this analysis must be added. PLSS data lack quantitative data related to herbaceous taxa. Nonetheless, some of the plant species of greatest conservation concern in the area are small shrubs (e.g., *Alnus maritima* and *Quercus sinuata* var. *breviloba*) or herbaceous vegetation (e.g., *Epipactis gigantea*, *Penstemon oklahomensis*, and *Psoralea reverchonii*). Due to the nature of the PLSS data, changes in the abundance of these species between the two survey periods or relative to present will not be captured. By providing evidence of increased woody plant densities and woody plant encroachment in former grassland environments, ostensibly due to fire abatement and other land use practices, though, the PLSS data might help guide conservation and restoration efforts throughout the Arbuckle Mountains.

Indeed, despite several inherent limitations of PLSS data, the repeat survey data sets provide valuable information pertaining to the composition and structure of the western cross-timbers and the effects of early land conversion thereon. Although this study focused on a portion of the cross-timbers, the anthropogenic processes encountered here are indicative of changes that have occurred throughout the eastern deciduous forest of North America, namely, habitat fragmentation, fire abatement, and changes in grazing regimes. Our results regarding changes in community structure between the two surveys are applicable to our understanding of the process of mesophication occurring not only within the cross-timbers but within the larger eastern deciduous forest—where anthropogenic disturbances might long predate the historical documentation on which such assumptions are based. The repeat PLSS data for the area corresponding to a period of rapid demographic transition have provided us with unique insight into these ecological processes. ■

Literature Cited

Anderson, R. C., S. L. Jones, and R. Swigart. 2006. Modifying distance methods to improve estimates of historical tree density from General Land Office survey records. *Journal of the Torrey Botanical Society* 133 (3): 449–59.

Archer, S. 1995. Tree-grass dynamics in a *Prosopis* thornscrub savanna parkland: Reconstructing the past and predicting the future. *Ecoscience* 2:83–99.

Bahre, C. J., and C. F. Hutchinson. 2001. Historic vegetation change in La Frontera west of the Rio Grande. In *Changing plant life of La Frontera: Observations on vegetation in the United States/Mexico borderlands*, ed. G. L. Webster and C. J. Bahre, 67–83. Albuquerque: University of New Mexico Press.

Batek, M. J., A. J. Rebertus, W. A. Schroeder, T. L. Haithcoat, E. Compas, and R. P. Guyette. 1999. Reconstruction of early nineteenth-century vegetation and fire regimes in the Missouri Ozarks. *Journal of Biogeography* 26:397–412.

Bennett, A. F., and D. A. Saunders. 2010. Habitat fragmentation and landscape change. In *Conservation biology for all*, ed. N. S. Navjot and P. R. Ehrlich, 88–106. New York: Oxford University Press.

Bolliger, J., L. A. Schulte, S. N. Burrows, T. A. Sickley, and D. J. Mladenoff. 2004. Assessing ecological resoration potentials of Wisconsin (U.S.A.) using historical landscape reconstructions. *Restoration Ecology* 12 (1): 124–42.

Bourdo, E. A. 1956. A review of the General Land Office survey and of its use in quantitative studies of former forests. *Ecology* 37 (4): 754–68.

Bray, J. R., and J. T. Curtis. 1957. An ordination of upland forest communities of southern Wisconsin. *Ecological Monographs* 27:325–49.

Briggs, J. M., G. A. Hoch, and L. C. Johnson. 2002. Assessing the rate, mechanisms, and consequences of the conversion of tallgrass prairie to *Juniperus virginiana* forest. *Ecosystems* 5 (6): 578–86.

Cottam, G., and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. *Ecology* 37:451–60.

Curtis, J. T. 1956. The modification of mid-latitude grasslands and forests by man. In *Man's role in changing the face of the earth*, ed. W. L. Thomas, 721–36. Chicago: University of Chicago Press.

Dale, E. E. 1956. A preliminary survey of the flora of the Arbuckle Mountains, Oklahoma. *The Texas Journal of Science* 8:41–73.

Delcourt, H. R., and P. A. Delcourt. 1996. Presettlement landscape heterogeneity: Evaluating grain resolution using General Land Office survey data. *Landscape Ecology* 11 (6): 363–81.

Doran, M. F. 1976. Antebellum cattle herding in the Indian territory. *Geographical Review* 66 (1): 45–85.

Dupouey, J. L., E. Dambrine, J. D. Laffite, and C. Moares. 2002. Irreversible impact of past land use on forest soils and biodiversity. *Ecology* 83 (11): 2978–84.

Dyksterhuis, E. J. 1948. The vegetation of the western cross timbers. *Ecological Monographs* 18:325–76.

———. 1957. Savannah-concept and its use. *Ecology* 38:435–42.

Engle, D. M., T. G. Bidwell, and M. E. Moseley. 1997. Invasion of Oklahoma rangelands and forests by eastern red cedar and Ashe juniper. Circular E-947, Oklahoma Cooperative Extension Service, Stillwater, OK.

Engle, D. M., T. N. Bodine, and J. F. Stritzke. 2006. Woody plant community in the cross timbers over two decades of brush treatments. *Rangeland Ecology Management.* 59:153–62.

Fagin, T. D., and B. W. Hoagland. 2002. In search of the forest primeval: The use of land survey records in reconstructing past landscapes and evaluating human impact. *North American Geographer* 4:1–20.

Forman, R. T. T. 1995. *Land mosaics: The ecology of landscapes and regions*. New York: Cambridge University Press.

Fritschle, J. A. 2008. Reconstructing historic ecotones using the Public Land Survey: The lost prairies of Redwood National Park. *Annals of the Association of American Geographers* 98 (1): 24–39.

Gibson, A. M. 1981. *The Chickasaws*. Norman: University of Oklahoma Press.

Grimm, E. C. 1984. Fire and other factors controlling the big woods vegetation of Minnesota in the mid-nineteenth century. *Ecological Monographs* 54:291–331.

Hoagland, B. W. 2006. Township & range survey system. In *Historical atlas of Oklahoma*, ed. C. R. Goins and D. Goble, 320. Norman: University of Oklahoma Press.

Hoagland, B. W., A. K. Buthod, I. H. Butler, P. H. C. Crawfor, A. H. Udasi, W. J. Elisens, and R. J. Tyrel. 2008. *Oklahoma vascular plants database*. Norman: Oklahoma Biological Survey, University of Oklahoma. http://www.oklahomaplantsdatabase.com (last accessed 18 February 2013).

Hoagland, B. W., I. H. Butler, F. L. Johnson, and S. Glenn. 1999. The cross timbers. In *Savannas, barrens, and rock outcrop plant communities of North America*, ed. R. C. Anderson, J. S. Fralish, and J. M. Baskin, 231–248. New York: Cambridge University Press.

Hoagland, B. W., and D. J. Hough. 2008. *Upland forests of Oklahoma: A searchable database of information from Rice and Penfound (1959) dataset*. Norman: Oklahoma Biological Survey, University of Oklahoma. http://www.biosurvey.ou.edu/rice_and_penfound/index.html (last accessed 2 February 2009).

Hoagland, B. W., and F. L. Johnson. 2001. Vascular flora of the Chickasaw National Recreation Area, Murray County, Oklahoma. *Castanea* 66 (4): 383–400.

Hopkins, M. 1941. The floristic affinities of the Arbuckle Mountains in Oklahoma. *American Journal of Botany* 28:16.

Hutcheson, H. L., Jr. 1965. Vegetation in relation to slope exposure and geology in the Arbuckle Mountains. Doctoral dissertation, University of Oklahoma, Norman, OK.

Hutchison, M. 1988. A guide to understanding, interpreting, and using Public Land Survey field notes in Illinois. *Natural Areas Journal* 8 (4): 245–55.

Irving, W. [1835] 1959. *A tour on the prairies*. Norman, OK: University of Oklahoma Press.

Johnson, F. L., and P. G. Risser. 1975. Quantitative comparison between an oak forest and an oak savannah in central Oklahoma. *The Southwestern Naturalist* 20 (1): 75–84.

Kennedy, R. K. 1973. An analysis of selected Oklahoma upland forest stands including both overstory and understory components. Doctoral dissertation, University of Oklahoma, Norman, OK.

Kronenfeld, B. J., and Y. Wang. 2007. Accounting for surveyor inconsistency and bias in estimation of tree density from presettlement land survey records. *Canadian Journal of Forest Research* 37 (11): 2365–79.

Langram, G., and N. R. Chrisman. 1988. A framework for temporal geographic information. *Cartographica* 25 (3): 1–14.

Little, E. L., Jr. 2000. *Forest trees of Oklahoma*. Publication No. 1, Revised Edition No. 16. Oklahoma City: Oklahoma Forestry Services, State Department of Agriculture.

Liu, F., D. J. Mladenoff, N. S. Keuler, and L. S. Moore. 2011. Broadscale variability in tree data of the historical Public Land Survey and its consequences for ecological studies. *Ecological Monographs* 81 (2): 259–75.

Lutz, H. J. 1930. Original forest composition in northwestern Pennsylvania as indicated by early land survey notes. *Journal of Forestry* 28:1098–1103.

Maines, K. L., and D. J. Mladenoff. 2000. Testing methods to produce landscape-scale presettlement vegetation maps from the U.S. Public Land Survey records. *Landscape Ecology* 15:741–54.

Mladenoff, D. J., and E. A. Howell. 1980. Vegetation change on the Gogebic Iron Range (Iron County, Wisconsin) from 1860s to the present. *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters* 68:74–89.

Moore, J. M. 1855. *Instruction to the surveyors general of public lands of the United States for those surveying districts established in and since the tear 1850*. Washington, DC: A.O.P. Nicholson, Public Printer.

Morris, J. W. 1947. Arbuckle Mountain ranching area. *Economic Geography* 23 (3): 190–98.

Motzkin, G. D., P. Wilson, D. R. Foster, and A. Allen. 1999. Vegetation patterns in heterogeneous landscapes: The importance of history and environment. *Journal of Vegetation Science* 10 (6): 903–20.

National Climatic Data Center. 2012. Climate data online. http://www.ncdc.noaa.gov/oa/ncdc.html (last accessed 25 June 2012).

Nowacki, G. J., and M. D. Abrams. 2008. The demise of fire and the "mesophication" of forests in the eastern United States. *BioScience* 58:123–38.

Owen, R. L. 1886. Owen to Commissioner of Indian Affairs, September 20, 1886. In *Report of the Commissioner of Indian Affairs for 1886*, 146–61.

Radeloff, V. C., D. J. Mladenoff, and M. S. Boyce. 2000. A historical perspective and future outlook on landscape scale restoration in the northwest Wisconsin pine barrens. *Restoration Ecology* 8 (2): 119–26.

Rempel, R. 2008. *Patch Analyst for ArcGIS®*. Thunder Bay, ON, Canada: Centre for Northern Forest Ecosystem Research, Ontario Ministry of Natural Resources.

Rice, E. L., and W. T. Penfound. 1959. The upland forests of Oklahoma. *Ecology* 40 (4): 593–607.

Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: A review. *Conservation Biology* 5 (1): 18–32.

Schulte, L. A., and D. J. Mladenoff. 2001. The original U.S. Public Land Survey records: Their use and limitations in reconstructing presettlement vegetation. *Journal of Forestry* 99:5–10.

Shutler, A., and B. W. Hoagland. 2004. Vegetation patterns in Carter County, Oklahoma. 1871. *Proceedings of the Oklahoma Academy of Science* 84:19–26.

Smith, B. E., P. L. Marks, and S. Gardescu. 1993. Two hundred years of forest cover changes in Tompkins County, New York. *Bulletin of the Torrey Botanical Club* 120:229–47.

Sørensen, T. 1957. A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons. *Biologiske Skrifter* 5 (4): 1–34.

Stewart, L. O. 1935. *Public land surveys: History, instructions, methods*. Ames, IA: Collegiate Press.

Stewart, O. C. 2002. *Forgotten fires, Native Americans and the transient wilderness*, ed. H. T. Lewis and M. K. Anderson. Norman: University of Oklahoma Press.

Suneson, N. H. 1997. *The geology of the eastern Arbuckle Mountains in Pontotoc and Johnston Counties, Oklahoma: An introduction and field-trip guide*. Norman: Oklahoma Geological Survey.

Trewartha, G. T. 1980. *An introduction to climate*. New York: McGraw-Hill.

Wang, Y.-C. 2005. Presettlement land survey records of vegetation: Geographic characteristics, quality, and modes of analysis. *Progress in Physical Geography* 29 (4): 568–98.

Whitney, G. G., and J. P. DeCant. 2001. Government Land Office surveys and other early land surveys. In *Historical ecology handbook*, ed. D. Egan and E. A. Howell, 147–76. Washington, DC: Island Press.

Zhang, Q., K. S. Pregitzer, and D. D. Reed. 2000. Historical change in the forests of the Luce District of the Upper Peninsula of Michigan. *American Midland Naturalist* 143:94–110.

TODD D. FAGIN is a postdoctoral research fellow with a joint appointment between the Department of Geography and Environmental Sustainability and the Oklahoma Biological Survey at the University of Oklahoma, 100 E. Boyd St., SEC Suite 510, Norman, OK 73019. E-mail: tfagin@ou.edu. His research interests include land use/land cover change, historical and contemporary vegetation mapping, and approaches to GIS education.

BRUCE W. HOAGLAND is a professor with a joint appointment between the Department of Geography and Environmental Sustainability and the Oklahoma Biological Survey at the University of Oklahoma, 100 E. Boyd St., SEC Suite 510, Norman, OK 73019. E-mail: bhoagland@ou.edu. His research interests include plant biogeography, vegetation classification, and floristic analysis.